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REPORT ON FEASIBILITY STUDY OF POTENTIAL APPROACHES TO UPGRADE EXISTING EMERGENCY LOCATOR TRANSMITTERS (ELT)

TRANSPORTATION DEVELOPMENT CENTRE
Policy and Coordination Group
Transport Canada

LEIGH INSTRUMENTS LIMITED
August 1989

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The contents of this report reflect the views of Leigh Instruments Limited and not necessarily the official view or opinions of the Transportation Development Centre of Transport Canada.

Please note that as of May 25, 1989, firm cost data for Canadian Search and Rescue operations have not been delivered to Leigh Instruments in time for inclusion in this report. Therefore the SAR cost figures in Sections 5 and 6 are estimates.

Un sommaire en français de ce rapport est inclus avant la table des matières.

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16. Abstract

The purpose of this study was twofold: a) to determine whether it is economically feasible to improve the reliability of existing emergency locator transmitters (ELTs), and b) to propose a field test plan to evaluate the feasibility of using ELTs conforming to Technical Standard Order (TSO)-C91a in the Canadian aviation environment.

ELT maintenance data were analyzed and categorized. Retrofittable improvements were analyzed. Aircraft accident data were utilized to arrive at a cost-effective field test plan.

The study found that ELT low reliability is primarily related to G-switch malfunctions and battery failures. The approximate cost of retrofit is $700.00 per aircraft. The field test plan calls for a fleet of 100 aircraft and a two-year test duration in order to observe sufficient ELT activations.

The following conclusions were drawn from the study:

a) It is not economically feasible to upgrade existing ELTs; and
b) It is sufficient to use 100 aircraft for a two-year field test period in order to yield sufficient ELT activation data provided that the right combinations of aircraft type, runway type and frequency of use are chosen.

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16. Résumé

La présente étude visait un double objectif: a) déterminer la faisabilité économique d'améliorer la fiabilité des radiobalises de détresse existantes, et b) proposer un plan d'expérimentation sur le terrain visant à évaluer la possibilité d'utiliser des radiobalises de détresse ELT, conformes à l'ordonnance technique TSO-C91a dans le contexte aéronautique canadien.

Les données d'entretien des radiobalises de détresse ont été analysées et classées par catégorie. Des améliorations rétro-adaptables ont été étudiées. Les données relatives aux accidents d'avions ont servi à mettre au point un plan d'expérimentation sur le terrain économique.

L'étude a établi que le faible taux de fiabilité des radiobalises de détresse est d'abord lié aux défectuosités des capteurs-interrupteurs accélérométriques et aux pannes des batteries. Le coût de rééquipement approximatif est évalué à 700$ par aéronef. Le plan d'expérimentation sur le terrain prévoit d'observer pendant une période de deux ans le comportement de radiobalises ELT installées à bord de cent aéronefs.

L'étude a permis de dégager les conclusions suivantes:

a) La modernisation des radiobalises existantes ne constitue pas une solution acceptable; et

b) Une period d'expérimentation sur le terrain de deux ans, portant sure une centaine d'aéronefs, suffit pour recueillir assez de données sur le fonctionnement des radiobalises de détresse pourvu qu'on ait choisi un échantillonnage représentatif des types d'aéronefs et de pistes d'atterrissage, et que leur fréquence d'utilisation soit adéquate.

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Radiobalise de détresse, modernisation, faisabilité, entretien, TSO-C91a, aviation générale, plan d'expérimentation sur le terrain, aéronef, batterie, lithium.	Le Centre de développement des transports dispose d'un nombre limité d'exemplaires.

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Summary

1. INTRODUCTION

Leigh Instruments Ltd. was awarded a contract from the Transportation Development Centre (TDC), Transport Canada, to perform a two-part study on:

(a) The development of a plan for field testing of Emergency Locator Transmitters (ELTs) built to meet the performance requirements of the Federal Aviation Authority's TSO-C91a, in the Canadian aviation environment; and

(b) The cost-effectiveness of upgrading existing ELTs to meet TSO-C91a.

The field test was required to provide some indication of the results which may be expected from TSO-C91a ELTs, and the upgrade study was needed to determine the advantages and disadvantages of upgrading existing ELTs to TSO-C91a so that expenses to Canadian pilots can be kept to the minimum consistent with adequate protection.

2. STUDY METHOD

2.1 Field Test Plan

Aircraft accident data were analyzed by Leigh in order to recommend a price-effective field test plan. Where there were insufficient data to make statistically valid conclusions, assumptions were made and, hence, approximate results and conclusions were arrived at.

2.2 Feasibility of Upgrading Existing ELTs

Leigh approached the study as a four-part exercise. First, with assistance from TDC, Leigh acquired the rav data from an ELT Maintenance Defect Survey which had been conducted by the Avionics Inspection Branch of Transport Canada in 1986-87. This material, along with applicable manufacturers' service bulletins and manuals, and relevant reports and literature re ELTs, formed the data base on which the company built its analysis.

Next, the data were analyzed to categorize the failures or defects both by type of defect and by ELT model. The report lists the defects in descending order of frequency.

3. RESULTS AND CONCLUSIONS

3.1 Field Test Plan

TDC desired a limit of two years for the test period and a limit of 100 new ELTs (TSO-C91a) to be used during the test period.

Leigh suggests the following test plan:

1- Each of the 100 aircraft chosen is to have a new ELT (TSO-C91a) installed.

2- The ELTs are to be monitored and, in case of an accident or false alarm, the ELTs' function should be recorded.

3- The 100 aircraft participating in the test plan should be chosen based on the worst combination of:

   a) Single reciprocating engine fixed wing.

   b) Highest number of landings and takeoffs per year.

   c) Gravel, grass or water runway, especially if covered with snow or ice.

   d) Least experienced pilots.

   e) Aircraft regularly operating in wide variations of air temperature and pressure, and other adverse atmospheric conditions (e.g. fog, snow, etc.)

If the above conditions are met, the number of incidents, including false alarms, during the two years' test period are expected to be 11 to 26 per 100 aircraft.

A meeting of a sub-group of the ELT Working Group was held on May 13, 1988, at the Transport Canada-Aviation Group Office in Ottawa. The group met to discuss two methods of conducting the ELT field trials:

(a) to use the test ELT in addition to an existing ELT; or
(b) to use the test ELT only in each test aircraft.

The group's decision was that test ELTs only be installed in lieu of, rather than along with, existing ELTs. To ensure against legal liability in the event of failure to activate, action was taken to have the test ELTs, ARNAV-100 and ARNAV-130, certified for installation in Canadian aircraft.

3.2 Feasibility of Upgrading Existing ELTs

The study shows that the most frequent defects were over-aged batteries and circuit card failures, followed closely by G-switch malfunctions and corrosion.

The study activity continued with recommendations to upgrade the various components and modules to minimize malfunctions. The report concludes with a cost/benefit analysis and an estimate of the cost per ELT to implement the most effective improvements. The total cost was estimated at $700 (Cdn) per unit before taxes, as compared to the target cost of $500 (US).

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Sommaire

1. INTRODUCTION

Leigh Instruments Ltd. s'est vu attribuer un contrat par le Centre de développement des transports (CDT), de Transports Canada, en vue de mener une étude en deux volets visant à:

a) élaborer un plan d'expérimentation sur le terrain dans un contexte aéronautique canadien des radiobalises de détresse (ELT) répondant aux normes de performance de la TSO-C91a de Federal Aviation Authority;

b) déterminer s'il est rentable de moderniser les radiobalises de détresse existantes en vue de satisfaire aux exigences de la TSO-C91a.

L'expérimentation sur le terrain était nécessaire afin d'avoir une idée de la performance des radiobalises conformes à la TSO-C91a, tandis que le deuxième volet de l'étude devait permettre de déterminer les avantages et les désavantages de la modernisation des radiobalises existantes pour les rendre conformes à la TSO-C91a, l'objectif étant de minimiser les coûts afférents pour les pilotes canadiens tout en leur assurant une protection adéquate.

2. MÉTHODOLOGIE DE L'ÉTUDE

2.1 Plan d'expérimentation sur le terrain

Les données relatives aux accidents impliquant des aéronefs ont été analysées par la société Leigh en vue du recommander un plan d'expérimentation sur le terrain rentable. Dans les cas où les données disponibles étaient insuffisantes pour permettre de tirer des conclusions statistiquement valables, les conclusions ont été établies à partir de résultats approximatifs basés sur des hypothèses.

2.2 Faisabilité de la modernisation des radiobalises de détresse existantes

La société Leigh a abordé cette étude comme un exercice en quatre parties. D'abord, avec l'aide du CDT, elle s'est assurée l'accès aux données brutes d'une étude sur les défectuosités et l'entretien des radiobalises de détresse, qui avait été menée en 1986-1987 par le Service du contrôle de l'avionique de Transports Canada. Ces renseignements ainsi que les manuels et bulletins d'entretien des fabricants, les rapports pertinents et la documentation relative aux radiobalises de détresse, ont constitué la base de données à partir de laquelle Leigh a établi son analyse.

Par la suite, les données ont été analysées afin de classer les pannes et les défaillances par type et par modèle de radiobalise en cause. Le compte rendu dresse une liste des défaillances par ordre décroissant de fréquence.

3. RÉSULTATS ET CONCLUSIONS

3.1 Plan d'expérimentation sur le terrain

Le CDT souhaitait mettre à l'essai un nombre maximum de cent nouvelles radiobalises (conformes à la TSO-C91a) pendant une période d'une durée maximale de deux ans.

La société Leigh a soumis le plan d'expérimentation sur le terrain suivant:

1. Installer une nouvelle radiobalise de détresse (conforme à la TSO-C91a) dans les cent aéronefs choisis.

2. Contrôler les radiobalises de détresse et, en cas d'accident ou de fausse alarm, faire une inscription à cet effet au dossier.

3. Constituer un échantillon de cent aéronefs réunissant la pire combinaison des facteurs suivants:

a) Monomoteur (à pistons) à voilure fixe.

b) Décollages et atterrissages annuels très nombreux.

c) Pistes gazonnées ou de gravier, ou plan d'eau, surtout enneigés ou glacés.

d) Pilotes très peu expérimentés.

e) Aéronefs soumis régulièrement à des températures et des pressions atmosphériques variant sur une grande échelle et à d'autres conditions météorologiques défavorables (brouillard, neige, etc.)

Lorsque les conditions ci-dessus se vérifient, le nombre d'incidents, y compris les fausses alarmes, enregistrés au cours de la période d'essai de deux ans, devrait se situer entre 11 et 26 pour 100 aéronefs.

Un sous-groupe du groupe travail sur les radiobalises s'est réuni le 13 mai 1988 aux bureaux du groupe Aviation de Transports Canada à Ottava. Le groupe s'est réuni pour discuter de deux méthodes envisagées pour l'expérimentation sur le terrain des radiobalises:

a) Utiliser une radiobalise d'essai en plus de la radiobalise de détresse existante; ou

b) N'utiliser qu'une radiobalise d'essai dans chaque aéronef participant.

Le groupe a décidé de n'utiliser que les radiobalises d'essai en remplacement des radiobalises de détresse existantes. Afin de prévenir toute poursuite en cas de panne de la radiobalise, des mesures ont été prises afin que les radiobalises d'essai, ARNAV-100 et ARNAV-130, soient homologuées pour équiper les aéronefs canadiens.

3.2 Faisabilité de la modernisation des radiobalises de détresse existantes

L'étude a montré que les défaillances les plus fréquentes sont dues aux batteries trop vieilles et aux plaquettes de circuits imprimés, suivies de près par les défaillances des capteurs-interrupteurs accélérométriques et la corrosion.

L'étude a débouché sur les recommandations visant à la modernisation de divers composants et modules en vue de minimiser les pannes. Le rapport se termine par une analyse coût-avantages et une évaluation du coût unitaire des améliorations les plus valables. Le coût total a été évalué à 700 $ (canadiens) par unité avant taxes, en comparaison du coût visé de 500 $ (américains).

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SECTION 1

INTRODUCTION

1.1 Scope

In 1987 Leigh Instrument Limited was avarded a contract to study the feasibility of upgrading existing Emergency Locator Transmitters (ELTs). This study was performed to develop portions of two initiatives which have been identified by the ELT Working Group formed by the Assistant Deputy Minister of Aviation. The study comprises:

a) a development of a plan for field testing nev ELTs conforming to the Federal Aviation Administration (FAA) Technical Standard Order TSO-C91a (1).

b) An investigation and assessment of the cost-effectiveness to modifying current ELTs with more reliable components and adding audio/visual monitors, in order to meet TSO-C91a requirements.

1.2 Background

Most general aviation aircraft which are operated within Canada carry ELTs which conform to regulations which are laid down by Transport Canada. It is generally recognized that ELTs have contributed to the prompt detection and location of numerous aviation accidents. It is equally well known that there are many problems associated with the ELTs which are in common use in 1987. The first major problem is the tendency of ELTs to be activated inadvertently. In Canada, in a typical year, about 600 ELT activations occur. But only 40 or so of these will be actual downed aircraft cases (ref. Appendix D). The over 90% false alarm rate is costly from a Search and Rescue standpoint, even though many cases are resolved before launching a SAR aircraft. Similarly, ELTs fail to survive and operate correctly in about 60 per cent of real accidents. These figures are similar to those recorded in the United States.

Activation failures have been attributed to battery failure, degradation due to corrosion, mechanical stress failure, and malfunction of the G-switch. The principal cause of false alarms has been determined to be sensitivity of G-Switches to vibration.

The United States Radio Technical Commission for Aeronautics (RTCA) was tasked with a re-examination of the technical and performance standards of ELTs, with the assistance of an international group of government and industrial agencies.

(1) Numbers in brackets designate references listed at the end of the report.

This examination resulted in a document (RTCA/DO-183 (2)) which was approved by the US FAA for use under Technical Standard Order TSO C91a (1).

The salient features of DO-183 are the inclusion of an audio/visual monitor for inadvertent activations, an improved G-switch performance requirement, and a spectral purity requirement to enhance SAR satellite detection of the ELT transmission.

SECTION 2

FIELD TEST PLAN

2.1 Objectives of Test

The objective of this test is to determine whether ELTs which conform to the requirements of TSO-C91a perform significantly better in the Canadian context than do currently used ELTs which meet the requirements of TSO-C91 (3). In particular it is desired to determine whether the new-generation ELTs have a higher probability of surviving a real crash, activating and operating correctly afterwards. It is also required to measure the false alarm rate of these new ELTs and to compare it to the false alarm rate observed for the currently used ELTs.

The results of this field test are to be used to provide guidance to regulatory personnel within the Department of Transport. Since this is a matter of some importance it is necessary to limit the duration of the field test to no longer than 2 years.

2.2 Theory of Test

In this section the theory upon which the recommended test plan is based is developed. First, a number of terms are defined. This includes the ELT false alarm rate and the ELT probability of valid operation. A model of the statistical processes involved is presented and may be used to predict bounds on validity of test results.

2.2.1 Definitions

2.2.1.1 False Alarm

An ELT may be operated manually or transmission may be initiated by an acceleration sensor, commonly known as a "G-switch". The theory of operation is that the "G-switch" is triggered by the high deceleration which is experienced in a crash. In any such system there is a finite probability that the "G-switch" will activate the ELT when in fact no accident has occurred. This inadvertent transmission is often known as a false alarm. For the purposes of this field test this may be known as the first stage false alarm.

ELTs which meet the requirements of TSO-C91a include a monitor circuit which notifies a pilot when his ELT is active. It is expected that the majority of inadvertent activations of these new ELTs will result in very short transmission times before the pilot resets the unit. Short-duration transmissions are very unlikely to result in a Search and Rescue "incident", hence a short alarm should not be recorded as a false alarm.

For this field test, a false alarm is an inadvertent activation which:

a) does not involve a crash, and
b) results in unnecessary deployment of search vehicles.

For the purpose of the test, a crash is defined as any accident which will cause substantial damage to the aircraft, or serious or fatal injury to the occupants .

2.2.1.2 Probability of Valid Operation

An ELT is required to survive a crash, and to help Search and Rescue forces arrive on the scene in a timely manner. The probability of valid operation is defined as the probability that the ELT will:

a) survive the crash
b) be activated by the crash, and
c) will transmit a signal which is strong enough to be detected by an overflying satellite.

This probability depends both upon the nature of the crash, and upon the construction and installation of the ELT.

2.2.2 Observation of Probability of Valid Operation

The primary objective of this field trial is to determine the probability that an ELT will survive and operate successfully after a crash. In order to make a valid assessment of the usefulness of a particular methodology it is advisable that the underlying statistical process be modeled.

The first observation to be made is that it will be necessary to have ELTs on board aircraft which crash in order to assess the unit's survival rate. Assume that the accident rate for a particular type of aircraft and usage category is proportional to its number of flights (rather than its flying hours).

Further assume that the probability that an accident will occur on a given flight, for a particular type of aircraft (a) and usage category (c) is denoted by P (a,c).

The probability that this aircraft will be involved in an accident in m flights may be described as a binominal process;

$$prob_no_accident_in_m_flights=[1-P(a,c)]^m$$

Given the modern safety record of aircraft this may be approximated by

prob_accident_in_m_flights=m*P(a,c)

That is, the probability of accident is proportional to the number of flights.

The second observation is that the probability that an ELT will survive and operate successfully may be modeled as a binomial process as well. Let q denote the probability that an ELT will survive and function after a crash. Then

Prob (r successes, given n crashes)=

$C(n,r)xq^{r} \times (1-q)^{(n-r)}$

where C(n,r) is the combinatorial function

This equation may be used to estimate the confidence intervals which may be achieved, given the results from n crashes. Clearly the confidence limits depend upon the true value of q as well as n. To achieve a confidence factor which is generally satisfactory it is desirable that data from at least 20 crashes be considered although the general performance of the ELT can be inferred from as few as 10 crashes.

The general strategy is obvious. It is desirable that ELTs be placed upon planes which are in high-risk groups and which make frequent takeoffs and landings.

2.2.3 Observation of False Alarm Rate

The observation of false alarm rate is of secondary importance in this field trial. Two methods may be used to evaluate false alarms. Either the pilot/operator may be asked to cooperate by filling a history form as first stage false alarms are experienced, or the COSPA/SARSAT system may be used as a data-gathering tool. Both basic approaches have their merits and their drawbacks.

Historically ELTs have been inadvertently activated by many different mechanisms, not just by faulty "G-switches". No model has therefore been proposed for the probability distribution of inadvertent activations.

For comparison purposes it would also be very useful if a similar evaluation of false activations could be made for a control population of standard ELTs.

2.3 Pilot/Operator Participation

It is essential that all pilots/operators participating in the field test should maintain during the test period a good record of the following items;

a) First stage false alarms; i.e. any false activation of the ELT for any reason, and for any time period during which the pilot/operator shut the ELT off.

b) Second stage false alarm; i.e., a false alarm which is detected by a satellite or by other aircrafts ... etc. i.e. the pilots/operator was unaware of his ELT activation.

c) In case of accidents, beside filling the accident report in the normal fashion, the performance of the ELT should be recorded separately.

d) Separate log book or data sheet should be maintained to monitor the performance of the ELT during (a), (b) and (c) above.

2.4 Proposed Methodology

2.4.1 Selection of Control Population

The following represents a crude estimate of the number of expected incidents during the field test. They include false alarms which are also important to assess.

- Approx No. of new ELTs used in the test = 100 ELTs
- Approx No. of aircraft incidents in Canada (all aircrafts) per annum (See Appendix D) = 1,100 incidents
- Approx No. of aircrafts in Canada = 20,000 aircrafts
- Therefore, the number of expected incidents in those aircrafts (all types) with new ELTs during a two year period is:

  $N = 2 \times 100 \times 1100/20,000 = 11$ incidents.

  The above number includes ELT false alarm incidents which, according to Canadian SAR data in Appendix D, consist about 55% of all aircraft incidents. Therefore the number of actual accidents Na may be assigned the value 5.

  A much larger number of accidents (Na) can be made probable if the worst combination of aircraft type, frequency of use and airport conditions are chosen. A rough estimate of the expected improvement in the total number of accidents is given below:

1. Aircraft types: The use of fixed wing aircraft with a single reciprocating engine should increase N by a factor of 1.15 or more explained below:

From NTSB/ARG-87/03 (4) report (page 4);

Fixed wing accidents	2467
Single recip. Engine accidents	2180
Fixed wing accident rate	8.65 acc./100,000 flying hrs
Single recip. Engine accident rate	9.93 acc./100,000 flying hrs

From above we deduce the following;

% of SR. engine accidents = $\frac{2180}{2467}$ = 88%

A correct evaluation of Na factor involves knowing the ratio of No. of S.R. engine to total fixed wing engine aircrafts.

The data is not available at present.

From accident rates we have;

$$\frac{\text{S.R. engine}}{\text{total fixed wing}} = \frac{9.93}{8.65} = 1.15$$

2. Frequency of Use: From NTSB/ARG-87/03, page 33;

The accident rate due to landing, takeoff, approach, descent, taxi and climb is 68.8% for 1984 and 69.4 for 1985. Canadian Aircraft Safety Board data, Appendix E, shows that 56% of accidents occur at or within 8 km of an airport. Obviously, the more frequent the usage of an aircraft, the higher the probability it will have an accident. Depending on the frequency of use of the chosen aircrafts w.r.t. the frequency of use for the general population, the Na factor can be made very high. In the absence of statistics for the general population and for the chosen aircraft, Na is factored arbitrarily by 2.0.

3. Airport Condition: Gravel, grass and water runways (especially if they are covered with snow or ice) have the worst record in all aircraft accidents in Canada as shown in Canadian Aircraft Accidents reports for 1981 (5). Choosing private aircrafts with more frequent use of any of the above runways may increase Na by a factor of 1.5 approximately.

4. Pilot Experience: Pilots with less experience have higher probability of causing accidents compared with experienced pilots. Therefore, Na may increase by an arbitrary factor of 1.2.

Due to lack of all data required to make a good statistical analysis, the above analysis should be considered approximate. All four items discussed above are interdependent. Therefore, the final conclusion should be used as a guideline.

Using the worst combination of the above conditions, the number of expected accidents during the two years test period with only 100 aircraft may range from 5 to 20 accidents. Adding to that the estimated false alarm number of 6, the total of expected aircraft incidents ranges from 11 to 26.

2.5 Pilots/Operators Survey

In order to obtain a very good assessment of the new ELTs vs old ELTs, the worst possible combination as described in Section 2.4.1 should be chosen for both new and old ELTs. Therefore, a survey among Pilots/Operators should be made first in order to pick the most likely 100 candidates to participate in the field test. The survey should supply the following informations:

1. Aircraft type.
2. Frequency of use in each month of the year. (no. of landings and take offs).
3. Description of airport condition in each month of the year.
4. Pilot age and experience.

2.6 Canadian Flying Environment

Aircraft in Canada do considerable cross-country flying over a wide range of temperature, pressure, and terrains. Since ELTs are very important to aircraft operting in isolated areas, care should be taken to represent them adequately in the field trial even though the proposed methodology may tend to exclude them.

Conversely, training aircraft accidents do not resemble typical accidents in severity, even though they may form a large percentage of the accidents that occur near airports. Therefore it is suggested that not more than 10% of the test ELTs be installed in training aircraft.

SECTION 3

ANALYSIS OF THE ELT DEFECT DATA

3.0 Maintenance Defect Data Base

Transport Canada conducted a survey of ELT defects as found by avionics maintenance shops across Canada. Twenty maintenance shops participated in the survey during 1986 and 1987. From the survey forms returned the time interval used by each shop ranged from one to thirteen months, with an average time of 4.1 months. The forms, supplied by Transport Canada, provided pass/fail check columns. Seven columns were for operational performance, and six for defined defects. A column for remarks was also provided. An example of a filled-out form is shown in figure 3-1.

3.1 Component Failure By Frequency of Occurrence

3.1.0 General

The several avionics maintenance facilities which participated in the ELT Defect Survey reported a total of 1,092 ELT's inspected, serviced, or repaired. The total number of defects was 250 or 23% of the total submitted for inspection.

The following frequency of defects was observed from the survey data:

TABLE 3-1 DEFECTS BY FREQUENCY OF OCCURRENCE

Item	Type of Defect	Qty	% of Def	% of Surv
1	Battery replacement overdue	53	21.2	4.8
2	Crash activated switch malfunction	45	18.0	4.1
3	Corrosion	40	16.0	3.7
4	Circuit board failure	40	16.0	3.7
5	Antenna and/or RF connector failure	31	12.4	2.8
6	Battery failure	25	10.0	2.3
7	Miscellaneous defects	16	6.4	1.5
		250	100.0	22.9

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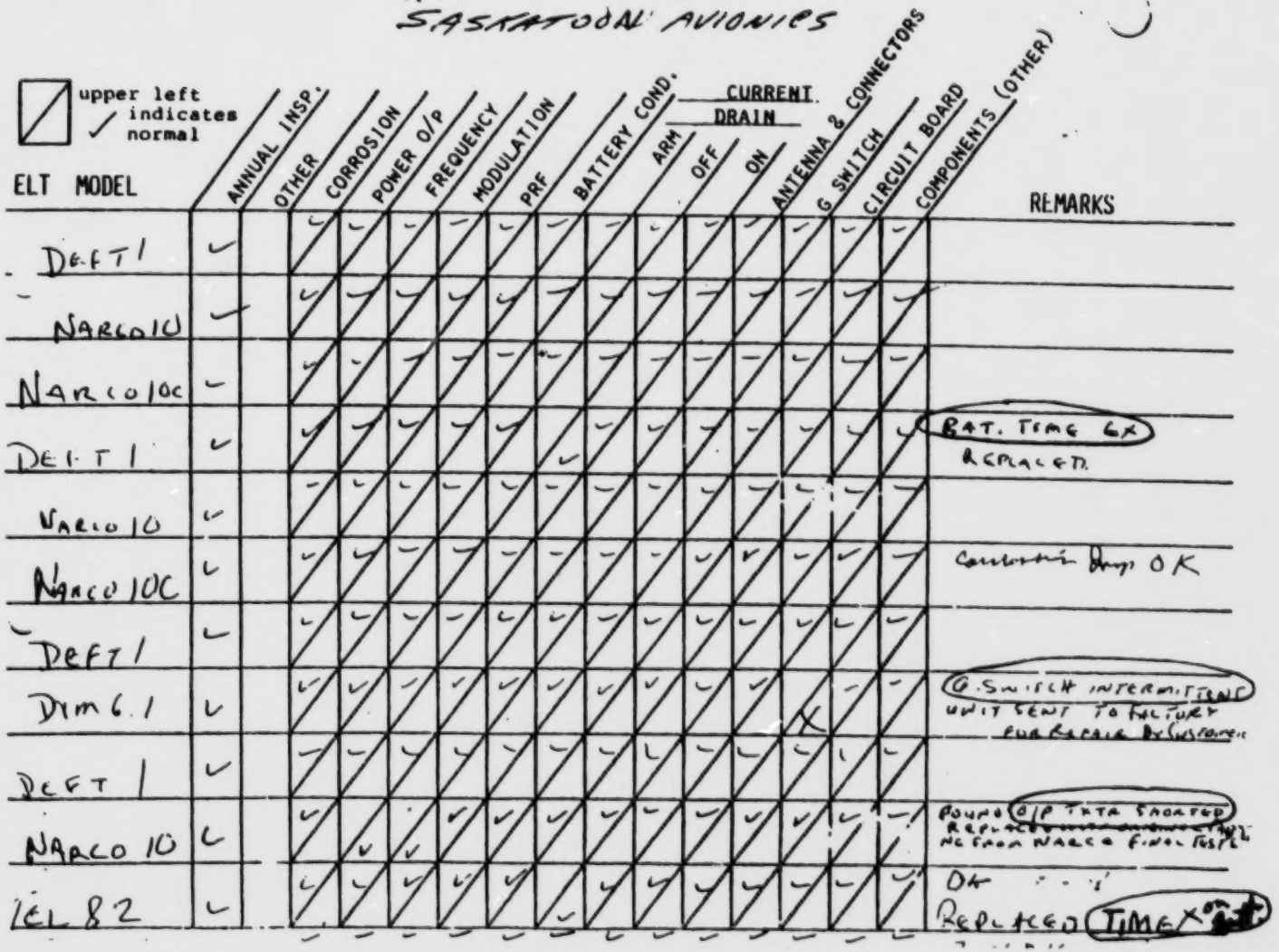

FIG 3-1: Sample Survey Form

TABLE 3-2 MAINTENANCE DEFECTS BY COMPONENT

CIRCUIT BOARD:	
Corrosion	2
Crystal	4
RF Oscillator	2
Power Amplifier	12
Modulator	16
Undefined	4
BATTERY REPLACEMENT DATE EXPIRED:	
Total	53
CRASH ACTIVATED SWITCH:	
Weak	8
Stiff	2
Intermittent or bouncing	3
Other	32
CORROSION:	
Battery leakage	17
Water damage	7
Undefined source	16
BATTERY DEFECTS:	
Less than two years life	15
Electrolyte leakage	4
Not approved by ELT manufacturer	6
ANTENNA & CONNECTOR:	
Corrosion	16
Breakage	1
Lost	2
Contact or connector damage	4
Other	8
MISCELLANEOUS DEFECTS:	
Switches	2
Connectors other than antenna	5
Lead wire damage	2
Accessories damage	1
Miscellaneous parts	7

3.1.1 Battery Replacement Overdue

ELT defects due to overdue battery replacement rank first at 21%. Although the dead battery may not be considered an equipment fault, it is definitely a major contributor to the high rate of ELT non-performance in crashes. Also, a lov battery, in conjunction with imperfect acceleration detection logic, may initiate false alarms. A major campaign is required to educate aircraft owners/pilots to pay attention to the manufacturers' recommendations for battery replacement.

3.1.2 Crash Activated Switch

Malfunctions of the crash activated or "G" switch accounted for 18% of the surveyed defects. Only 13 of the 45 reports made any attempt to define the G-switch failure. See Table 3-2. However, even those which met the requirements of the FAA's TSO C91 would probably malfunction in use (6, 7, 8). The currently used G-switches are essentially vibration detectors. Slamming doors and rough landings can produce the "high" frequency vibrations of amplitude that will cause the ELT to activate. On the other hand, in the event of a crash, lover amplitude vibrations can mask the long period acceleration, and thus prevent activation of the ELT.

TSO-C91a addresses the problems of ELT reliability. Among the new requirements is a definition of a G-switch acceleration-time characteristic empirically determined from actual and simulated crash measurements. Also the G-switch must function when subjected to lateral accelerations of up to 30g. One model of ELT among those surveyed comes close to satisfying the requirements of TSO C91a. It combines a fluid damped sensor with an electronics integrator.

However, the improvements of C91a over C91 are yet to be proven in the real world of general aviation usage. The new ELT field trial being proposed by Transport Canada will help to quantify the benefits of TSO-C91a in the Canadian aviation context.

3.1.3 Corrosion

Corrosion accounted for 16% of the reported defects (Table 3-2). Although only 17 cases identified battery leakage as the source, some of the undefined sources vere associated with older type ELT's which once had the old Lithium-Sulphur Dioxide batteries. As long as users continue to ignore battery replacement dates the risk of leakage from alkaline/magnesium batteries will continue. Better encapsulations or conformal coatings will be required on circuit assemblies, and more resistant plating on metal parts. The sources identified as water damage include the results of condensation, exposure to sea atmosphere, and contact between dissimilar metals.

3.1.4 Circuit Board Failures

The failures of electronic circuits at 40 comprised 16% of all defects. The majority of the circuit defects, as listed in Table 3-2 were apparently semiconductor and other electronic parts failures. Only about 5% were directly attributable to corrosion. The survey did not identify whether parts failures were due to electrical stress, or mechanical stress (e.g. - vibration, shock).

3.1.5 Antenna and Connector

Over 50% of antenna defects were breakage or losses by corrosion of built-in antennas. The majority of these were of a type made of inadequately plated steel ribbon. The next most frequent defect was damage or corrosion to RF connectors to external antennas.

3.1.6 Battery Failure

The most numerous battery defect was the failure to deliver at least two years of standby service life. Some of these failed batteries were warranty replacements but most were those that were discharged before the recommended replacement date. Two types of ELT in the survey showed a significant number of battery failures. The pointer C-4000 (97 inspected) had 5 battery failures out of a total of 32 recorded defects. Four of those failed batteries had discharged in less than two years. Likewise, the DEFT-1/1A (183 inspected) had 9 reports of short life batteries for 24 recorded defects. A few defects were batteries which had been allowed to remain fitted long after they had expired and then developed electrolyte leaks. Included with battery defects were those cases where the ELT had been refitted with a battery not approved by the ELT manufacture. Some ELT manufacturers claim that their battery packs are designed to be part of the RF tuning or loading of their output circuits. Although the third party batteries are approved by FAA and TC (ref 2.5), these manufacturers assert that, unless the battery packs are identical in materials and configuration, their equipment will not perform correctly with these batteries in place.

3.1.7 Miscellaneous Defects

The miscellaneous defects included broken switches, pinched or cut lead wires, damaged battery or accessory connectors, and damaged remote control accessories. The damage to connectors and accessories was by means other than corrosion.

3.2 ELT Model Defects in Order of Occurrence

3.2.0 General

Table 3-1 lists a total of 250 defects reported by the maintenance survey. Of these, 53 were attributed to user negligence in battery management. When the remaining 197 defects were sorted by ELT model, it was observed that over half were attributable to three models: the Pointer C-4000 (32/103 population), the DEFT-1/1A (24/183), and the Narco ELT-10 (66/261). The Leigh Sharc-7 was also noted to have a high defect rate. However, due to its model age (not manufactured since 1975) and its minority in the total population, it should not be considered seriously for upgrade. The defects by ELT model are listed in Table 3-3.

3.2.1 Pointer C-4000

The leading defect of this model was the high failure rate of circuit boards, followed by a high incidence of early battery mortality. As seen in Table 3-3, this model had 32 defects in a population of 103 units inspected.

Fourteen or nearly half of the defects were in the circuit board. Six of these defects were in the modulator circuit, and another five were apparently traced to the RF amplifier.

The C-4000 also experienced five battery defects. All of these were due to expiry before the replacement due date. Since there was no indication of warranty replacement, one may infer that either the battery quality is not up to par, or that the armed current drain is excessive.

3.2.2 DEFT-1/1A.

This model had 24 defects in 183 unit inspected.

Battery problems accounted for ten of the DEFT-1/1A defects. Another five defects were attributed to circuit boards. There were also significant G-switch and corrosion problems.

3.2.3 Narco ELT-10

The Narco ELT-10 series, at 261 units inspected, was the largest component of the surveyed population. The total number of defects was the greatest, but ranked second at 25 percent of its model population. Loss of the auxiliary antenna or the antenna contact was the most numerous defect. However, most of the antenna defects were caused by corrosion. Thus over 50% of the total ELT-10 defects were corrosion related.

3.3 Survey of ELT Suppliers

3.3.1 In December, Leigh sent out a questionnaire to several ELT supplier/manufacturers. The list of manufacturers was obtained from Transport Canada Notice N-AME-A0 12/86 dated May 30, 1986. A copy of the questionnaire, along with the names of firms to which was addressed, is included in Appendix D.

3.3.2 The responses to the questionnaire were disappointing; one telephone response and one written reply. The marketing manager of Dorne and Margolin telephoned to say that they would send an answer after consulting with engineering about the release of service procedures and schematic. Their written answer was never received. Then Technisonic Industries Limited (TiL) wrote in reply to questions 1 through 9. They declined to disclose service schematics or procedures.

3.3.3 The significant information in the TiL reply was that:

- They manufacture only one model, the Tel-82
- there are approximately 1758 in service in Canada
- several Tel-82 (no quantity given) are converted Rescue 88, the model fitted with magnesium battery (P/N 627484)
- they re-certify 177 Tel-82 per year plus 67 of other Garret Rescue 88 and 99 models
- not more than 30 units per year require factory repairs

TABLE 3-3: MAINTENANCE DEFECTS BY MODEL

ELT MODEL	INSPECTED	CIRCUIT BD	G-SWITCH	CORROSION	ANTENNA	BATTERY	OTHER	TOT. DEF.	% MODEL POP.	% TOTAL POP	% TOTAL DEF
POINTER C-4000	103	14	4	4	2	5	3	32	31	2.9	16.2
D & M ELT - 6/6.1	115	3	14	3	0	2	1	23	20	2.1	11.7
ELT -8/8.1	25	1	0	1	0	1	0	3	12	0.3	1.5
NARCO ELT -10/10C	261	7	6	20	26	4	3	66	25	6.0	33.5
DEFT - 1/1A	183	5	3	3	1	10	2	24	13	2.2	12.2
EBC-102/102A	255	5	3	0	1	1	1	11	4	1.0	5.6
-302	12	0	1	0	0	0	0	1	8.3	0.1	0.5
LEIGH SHARC 7/7K	76	3	9	5	0	1	2	20	26	1.8	10.2
TECHNISONIC TEL-82	32	1	2	1	1	0	2	7	22	0.6	3.6
CCC/COLLINS CIR-11	8	1	1	0	0	1	2	5	63	0.5	2.5
MARTECH EB-2 BCD	12	0	0	1	0	0	0	1	8	0.1	0.5
GARRETT RESCU 88	6	0	2	2	0	0	0	4	67*	0.4	2.0
TOTALS	1092	40	45	40	31	25	16	197		18.0	

* DEFECT RATE IS COLOURED BY FACT THAT TECHNISONIC NOW HAS THE RESCU 88 AND HAS CONVERTED THE MAGNESIUM BATTERY MODEL INTO THEIR MODEL TEL-82

SECTION 4

RECOMMENDATIONS FOR UPGRADE OF CURRENT ELTs

4.1 General

The design improvements listed and discussed below are not specific and are not aimed at one vendor or one particular ELT. In addition the comments are generic in form and do not limit the design of an individual ELT by an individual vendor. These comments should be considered as a checklist of good design practice for instruments subjected to the particular environment of the ELT and requiring the reliability implicit in a lifesaving equipment. It is not sufficient that an ELT work in a laboratory and pass laboratory tests. Its purpose is to operate under very adverse conditions and after a crash that may subject it to extremes in shock. This may occur after years of shelf life in the off condition or standby mode. This section proposes various upgrade recommendations without analyzing the cost impact to retrofit ELTs now in service. Section 5 will address a cost/benefit analysis of the recommendations as applicable to upgrade existing ELTs to meet requirements of TSO-C91a.

4.2 Recurrent Battery Problems

4.2.1 History

Since the first generation lithium-sulphur dioxide batteries were banned from general aviation use the majority of battery packs used in ELT's have been of the zinc-manganese/alkaline types, mostly utilizing D cells. While these have good capacity and temperature range of operation, there have been a number of recurring problems.

A review of the maintenance log statistics provided by Transport Canada highlights four main categories of entries:

(1) time expired batteries

(2) short life, significantly less than two years

(3) electrolyte leakage

(4) corrosion

4.2.1.1 Time Expiry:

The frequency of time expiry mostly can be attributed to negligence on the part of the users who fail to inspect ELTs as

part of general aircraft periodic inspections. Scheduling the ELT check for battery date as part of the annual inspection may in fact leave too great a period in which corrosion or other problems can develop. A more diligent enforcement of annual ELT inspections would also help in reducing other non-battery faults by early detection of incipient problems.

In any case a safety letter campaign to alert the general aviation users of ELT's to such problems is indicated: directing reminders to owners and pilots on a periodic basis should make them more avare of necessary checks.

4.2.1.2 Short Life:

Failure of the battery to survive for at least 2 years was observed as a significant defect in two of the ELT models inspected in the survey. See paragraph 3.1.5.

Short life may be caused by:

(a) low quality battery, or too long a period in inventory,

(b) condensation reaching the ELT battery or circuit board, resulting in current drain by way of a leakage path causing some level of circuit activation, or by providing a leakage path across the battery bus or wiring.

(c) extreme temperature conditions developing as a result of outside long-term exposure to hot weather and insulation. In hot weather an ELT installation that effectively heat sinks the ELT case to the aircraft structure or skin can result in battery temperatures reaching 75 degrees C in the peak of the diurnal cycle. This has two effects on an alkaline battery - it imposes considerable thermal cyclic stress internally in the cell structure and accelerates the self-discharge process. Self discharge is primarily dependent on high temperatures rather then temperature cycling. Since the rate of self-discharge approximately doubles every 10°C above 20°C, at 60°C the rate is increased 16 times.

4.2.1.3 Electrolyte Leakage:

Electrolyte leakage may be the result of complete discharge of the battery where the remaining active chemicals in the cells attack cell cases or the crimp seals internally. High temperatures attained in the diurnal cycles will accelerate self-discharge and shorten cell life, with early corrosion a definite possibility. Leakage may also be the consequence of a defective crimp seal, or a seal attacked by outside corrosion, as discussed below.

4.2.1.4 Corrosion:

Corrosion may result from three primary causes, chemical, electro-galvanic, or biological processes.
Chemical corrosion of ELT's can be caused by exposure to marine environments in which saline aerosols are present, or the ELT externally or internally has been exposed to casual chemical sources (salt air, sweaty hands, certain cleaning agents). Moisture is provided by condensation on the ELT exterior, and to the interior of the ELT if the case is not moisture and water proofed. The resulting saline solution will attack circuit board wiring and components chemically, as well as electro-chemically if the circuits are powered.

Electro-galvanic corrosion results when dissimilar metals are subjected to a moisture path between them. Where such metals are also part of electrical circuits, moist leakage paths between them also can result in electrochemical corrosion.

In moist tropical or sub-tropical climates where high humidity and condensation occur regularly molds and fungi may attack non-metals and metals. Any circuit not protected by encapsulation or fungicidal conformal coating will be vulnerable to fungal corrosion of both board and components.

4.2.2 Short Term Improvements

4.2.2.1 Shortened Life:

The cells used in ELT battery packs are stamped with their date of manufacture. The battery replacement date shall not exceed one-half of the stated cell life, or two years, whichever is the lesser. At the expiry date, the battery should still have sufficient energy to power an ELT for 48 hours at -20°C. In practice, however, the expected two years of service may be appreciably curtailed by:

(a) high temperature shelf storage due to storage on the top shelf in a hot warehouse, or exposed to sunshine while in stock over a protracted period before being put in service,

(b) in service in aircraft stored outside where high battery temperatures may be imposed, as well as thermal cycling (both daily and seasonally).

4.2.2.2 Storage:

Storage conditions are the responsibility of the dealer and incorrect storage is probably an infrequent occurrence.

Storage at 35 to 40 degrees F (+2°C to 5°C) is ideal if available, as long as the batteries are individually wrapped in a moisture proof bag for storage. When the battery is removed from cold storage it should be left in the bag long enough to come to room temperature before being removed for installation in an ELT (or other equipment).

4.2.2.3 Service Environment:

The diurnal heating cycle in aircraft parked outside can have deleterious effects on battery life. The installation of an ELT on a part of the structure offering good heat conduction has been found to impose peak battery temperatures of up to 75°C for appreciable periods of each daily temperature cycle in summer weather. Thermal isolation can be effected by inserting a heat insulation layer between the aircraft structure and the ELT, and between the ELT case and the battery cells.

4.2.3 Long Term Improvements

4.2.3.1 Service Environment:

Using a very stiff reinforced plastic mounting sub-plate would be a substantial improvement in thermal isolation, provided that the shock-pulse transmission is not affected. R.F. bonding to the structure can still be effected by use of narrow bonding braid strips or thin strap (shim stock) of no more than three inches length.

4.2.3.2 Low Battery Warning:

Battery status warning (low voltage) may also be provided by employing the system used in domestic smoke detectors. These emit a short acoustic 80db high frequency burst every 30 seconds when battery voltages drops below a pre-set level, and will continue the warning for a couple of days or more. This idea is of limited use for aircrafts flown occasionally.

4.2.3.3 Electrolyte Leakage and Corrosion:

The frequency of occurrences of electrolyte leakage will be substantially reduced if the measures suggested above for monitoring battery condition and reduction of battery stress are implemented. Routine annual ELT inspections and date checking, and heeded low-battery warnings will be effective in removing batteries which have run down for any reason. However, electrolyte leakage may still occur due to faulty cell seals on occasion and also as a result of moisture induced corrosion.

4.2.3.4 Moisture Control:

Moisture exclusion from the interior of an ELT is dependent on the efficiency of the case seals around the cover-case contact, and around connectors, switch apertures, and antenna fittings. Deterioration of the seals due to compression, physical damage, and oxidation dictate immediate replacement, and should be automatically performed when detected.

Encapsulation of the circuit assembly and battery, in the sizes and shapes to fill the cavities within the ELT, will minimize condensation entering leaking seals during barometric pressure changes either by weather or flight altitude excursions. The encapsulant should be a moderate density rigid foam offering low dielectric constant and dielectric losses, and should be a non-hygroscopic type. The foam will also protect the circuit card assembly against shock and vibration. Encapsulation is usually part of the manufacturing process of building ELT's.

In the case of non-encapsulated ELT models, application of a low-stress conformal coating is recommended. This represents an appreciable inspection, cleaning, reconditioning procedure for ELT's which are in poor condition, and may be more expensive than purchasing a more up-to-date model already encapsulated and/or conformally coated. Where possible, the battery should be an encapsulated type to at least keep moisture away from the cells, inter-cell wiring, and connector wiring.

4.3 Crash Activated Switch Problems

All properly designed ELT(s) must be equipped with or connected to reliably functional crash sensing devices. The device function is to sense the crash and signal the ELT to start transmitting. There are many different types of crash sensing devices. All devices, however, can be grouped into two main groups; namely, direct sensors and indirect sensors.

4.3.1 Direct Sensors "Frangible Switches"

Direct sensing is the most reliable means of sensing the crash. It is also the most expensive to install. Frangible switches are normally installed on the airframe directly under the skin of the aircraft at the most vulnerable locations in the aircraft such as the nose and the belly. If a crash occurs the switch will sense it directly. The switch is a part of an electric circuit connected to the ELT through cables. Hence, the crash is then relayed directly to the ELT. As with a G-switch sensor, the detection circuit is usually a "normally-open" DC latch circuit which reacts to a sustained closure of the sensor switch. The maintained closure is achieved only by fracturing the frangible switch.

Since the sensor is not contained within the ELT, Installation and Maintenance are very costly in comparison with other sensors.

Since the switch can produce the signal if and only if damage has occurred to the aircraft frame the chance of a false alarm is very remote. Proper shielding and grounding of the detection system can minimize the effects of EMI.

4.3.2 Indirect Sensors "G-Switches"

Indirect crash sensing is achieved by sensing an abnormal change in one or more of the aircraft parameters such as; velocity, acceleration, engine RPM, altitude .... etc.

Most ELTs use inertia switches to monitor the longitudinal deceleration. These crash activated switches are also known as G-switches. the most popular switches are;

(a) A cantilever wire with tip mass.

(b) A ball and magnet.

(c) A rolomite switch.

Performance of all ELTs utilizing G-Switch technology in accordance with TSO-C91 have been unsatisfactory. A high rate of false alarm (95%) and failure-to-activate in crash situations (50%) are characteristic of all ELTs designed to TSO-C91. The reasons behind the poor performance are;

(1) Inadequate specifications.

(2) Improper installation.

(3) Moisture.

4.3.3 Improvements to Crash Sensing

Improvements to the crash sensing devices can be achieved using simple retrofittable modifications or expensive new designs to TSO-C91a. The simple modifications are expected to provide marginal improvements to the already bad statistics surrounding present ELTs. Other retrofittable design changes might be very expensive to implement while the sensing performance might reach that of TSO-C91a specifications.

Explained below are some ideas arranged in ascending order to their cost and hence their expected effectiveness.

4.3.3.1 Basic Level Retrofit:

The two simple changes explained below are not costly to implement;

(a) Water Proofing; water proofing reduces the complaints of false and misactivations due to corrosion and electrical malfunctions. The simplest and least costly waterproofing is achieved by conformal coating applied by spraying or brushing immediately after the next service inspection procedure. Other more effective methods of applying conformal coating are explained in MIL standards.

(b) Proper adherence to the installation instructions.

4.3.3.2 Second Level Retrofit:

The second level retrofit includes the basic level (sec. 4.3.3.1) plus replacing the G-switch. The new proposed G-switch is the simple cantilever wire with a tip mass and with silicone oil for damping: the natural frequency of the switch should be around 8-12Hz. Hence, aircraft structural vibrations would not affect the internal performance of the switch. The cost of replacing the G-switch might be high and in some cases it might be next to impossible to achieve without substantial design changes. It should be easy to replace a cantilever switch with a new cantilever switch, however.

4.3.3.3 Third Level Retrofit:

This retrofit level includes all design modifications discussed in the previous retrofit (Sect. 4.3.3.2) plus an added analogue integration circuit. The G-values are then sensed and summed with respect to time. TSO-C91a activation parameters may then be used in the design of the circuit.

Third level retrofit is expected to be expensive to implement. A new ELT designed to TSO-C91a might be more cost effective.

4.3.3.4 Fourth level Retrofit:

This suggested retrofit is too costly for general aviation. It comprises the basic level (Sect. 4.3.3.1) plus replacing the G-switch with direct sensors (frangible switches) connected to the ELT with cables.

4.3.3.5 Other G-Switches:

It might be possible to design and produce a low frequency mechanical G-switch which conforms to TSO-C91a and performs the integration and summation of G-values by mechanical means instead of analogue circuitry. The development of such a

switch would have to be addressed in a major research program. Some ideas are listed below;

(1) Using a ball, soft springs (minimum of two), viscous liquid and a cylinder holds a promise for such a G-switch. Parameters, such as ball and cylinder diameters (Venturi effect), viscosity, spring stiffness, ball mass, ball density, etc. can be adjusted to achieve the required performance.

(2) Cylinders with pressure membranes and strain gauges may be used.

(3) Piezoelectrical materials may be used as self energized indicators.

Funding for the above research project is highly unlikely, however.

4.4 Circuit Card Deficiencies

4.4.1 General

The basis for the study of ELT circuit card deficiencies was the data extracted from the ELT maintenance survey reports provided by the several avionics maintenance facilities, as well as the analysis of a number of transmitter circuit designs and the in plant observation of several ELTs.

From the ELT maintenance reports it was difficult to pin point the actual causes of electronic component failures on circuit cards. The reporting forms did not allow for specific failed devices to be identified, but rather provided a go/no go checklist for parameters, such as frequency or power output, and for major ELT parts, such as circuit cards for G-switches. in several cases remarks on the forms identified failures on circuit cards to the actual failed device.

4.4.2 Probable Causes of Failure

4.4.2.1 The most common causes of damage to circuit boards and their components are vibration and corrosion - vibration can cause board circuits to delaminate, component leads to break, soldered wires to break and connectors to become intermittent. Vibration levels causing even lov stress levels in any metal element will cause fatigue in that element and eventual breakage. This is only a matter of accumulation of sufficient numbers of stress cycles over the life time of the component.

To avoid these minimum stress levels each component on the board and the board itself must be examined for possible resonances and either locked down to stop the resonance or attached through damping materials to absorb the energy.

Miniaturization of components generally reduces the size and weight of electronics and raises the resonant frequency, all of which are good. Miniaturization also can improve reliability by eliminating wiring and solder connections, and by better circuit component control. Miniaturization to the point of DIP packaging also reduces component change or drift due to effects of moisture and track to track contamination.

4.4.2.2 Analysis of ELT schematics indicated two potential problem areas. One is that in a number of cases components are designed in to circuits to operate close to their safe operating limits and therefore under a significant amount of stress. See failure rate (reliability) analyses in Appendix B. The second problem area was in the means of activating the ELT electronics upon detection of G-switch closures. In some cases there was insufficient or no filtering of G-switch closures. This would allow ELTs to be activated by short duration G-switch closures that might result from normal aircraft structural resonances. In other cases the large time constants of the activation circuit filter components may prevent ELTs from turning on during actual crashes.

4.4.2.3 Observations of circuit card assemblies revealed corrosion and poor lead attachment techniques to be areas of concern. Humidity, condensation and salt water residues are particularly bad for board stability and circuit shorting, and since the ELT container is likely to breathe with each change in barometric pressure and temperature on the ground or flying, these elements will be drawn into the ELT.

4.4.3 Design Guidelines

In order to improve the performance of ELT transmitter circuits it is recommended that the following guidelines be adhered to in the design of new ELTs and incorporated to the maximum extent possible in existing designs.

4.4.3.1 Parts Derating

As a minimum, parameters of electronic parts should be derated in accordance with the applicable derating factors specified in Table 4-1. The derating factors should be applied at the maximum ambient temperature of operation. This would ensure that parts are operated well within their safe operating limits, thereby reducing stress and increasing the devices reliability.

4.4.3.2 Discrete Semiconductor Selection

Discrete semiconductors such as transistors, diodes and tyristors should be selected at the JAN quality level. This ensures that device vendors will screen out parts with manufacturing aberrations that might cause failures under normal operating conditions in the field. JAN level devices will also be packaged in hermetically sealed cases thereby improving their resistance to moisture. If not at the JAN level semiconductors should as a minimum be selected in hermetically sealed packages for moisture resistance: metal cans for transistors and thyristors, glass cases for diodes.

4.4.3.3 Passive Component Selection

Passive components selected should be of the established reliability type. As in 2), this would greatly reduce the possibility of defective components reaching production circuit cards.

4.4.3.4 Integrated Circuit Selection

Integrated circuits should be hermetically sealed packages, such as ceramic dual-in-line cases or metal cans. This would improve their resistance to damage from moisture.

4.4.3.5 Variable Components

The number of variable components, such as capacitors, resistors, and inductors, should be minimized. Reliability would be improved since components with moving parts are more prone to mechanical failure than fixed devices. This would produce the added benefit of simplifying transmitter tuning and reducing the possibility of detuning in the field.

4.4.3.6 Conformal Coating and Encapsulation

Circuit card assemblies should be conformally coated to improve their resistance to moisture effects and reduce the possibility of damage due to corrosion.

Conformal coating of exposed circuit tracks will stabilize the board stray capacitances and greatly improve the board's long term stability and its calibration setting integrity. This is especially true of high frequency circuits. The function of the conformal coating is to form a clean, insulating barrier across circuit tracks and also to separate the board surface from external entry of dirt, moisture, oils, salts and any other contaminating substance detrimental to the circuit operation.

Another method is to encapsulate the entire circuit in a suitable material. Effects of dielectric constant, resistivity and dissipation factor must be accounted for, or a means of final adjustment provided after potting.

4.4.3.7 Wiring Harness Attachment

All flying leads connected to circuit card assemblies should be connected at solder terminals. This would reduce mechanical stress at the points of lead attachment and improve the reliability of connections.

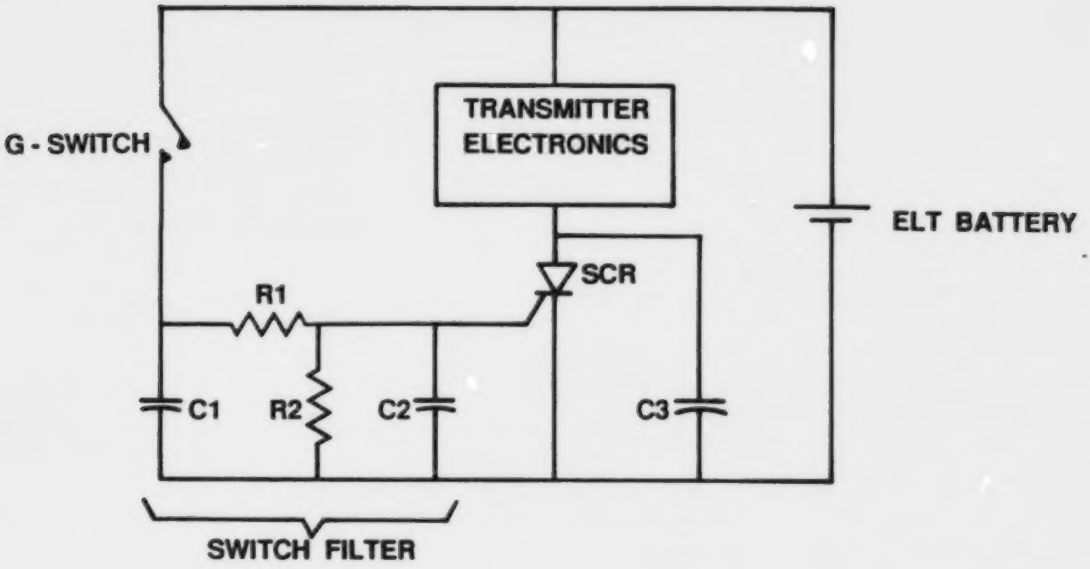

Figure 4.1 Typical ELT Activation Circuit

TABLE 4-1: PARTS DERATING

PART TYPE	PARAMETER	DERATING (from Spec. Value)
Integrated circuit, linear	Junction Temperature	125°C max.
	Supply Voltage	75%
	Input Voltage	75%
	Output Current	75%
	Offset Voltage	110%
	Operating Frequency	75%
Integrated circuit regulators	Junction Temperature	125°C
	Input Voltage, max.	75%
	Input voltage, min.	V_{in} + 10%
	Input-to-output voltage differential	15%
	Transients	95%
	Output current, max.	75%
Integrated circuit, digital	Junction temperature	125°C
	Supply voltage	V_{CC} ± 70% of specified tolerance
	Fanout/output current	75%
	Transients	V_{CC} + 1.0 VDC 75%

TABLE 4-1: PARTS DERATING (cont'd)

PART TYPE	PARAMETER	DERATING (from Spec. Value)
Transistors	Junction Temperature	125°C max.
	Voltage rating	70%
	Current rating	75%
	Power rating	50%
	Voltage transients	95%
Diodes, rectifier and switching	Junction Temperature	125°C max.
	Forward current	70%
	Reverse voltage	70%
	Power	50%
	Reverse recovery time	125%
	Peak repetitive current	75%
	Reverse voltage transients	95%
	Surge current	75%
Diode, zener and voltage reference	Junction temperature	125°C
	Forward current	70%
	Surge current	75%
	Power (zener)	50%
	Power (reference)	20%

TABLE 4-1: PARTS DERATING (cont'd)

PART TYPE	PARAMETER	DERATING (from Spec. Value)
Silicon controlled rectifiers	Junction temperature	125°C max.
	Surge current	75%
	Peak forward blocking voltage	70%
	Peak reverse voltage	70%
	Power	50%
	Turn on voltage gradient (dv/dt)	75%
	Forward current	75%
Optically coupled isolators	Junction temperature (gallium) (silicon)	100°C max. 150°C max.
	Voltage	70%
	Current	75%
	Power	50%
Phototransistor	Voltage transients	95%
Diode, LED	Junction temperature	100°C max.
	Forward current	70%
	Reverse voltage	70%
	Reverse current	33%
	Power	50%
	Reverse voltage transients	95%

TABLE 4-1: PARTS DERATING (cont'd)

PART TYPE	PARAMETER	DERATING (from Spec. Value)
Resistor, fixed, carbon composition RCR style	Power	60%
	Voltage	70%
Resistor, fixed metal film RNR styles	Power	60%
Resistor, fixed, film insulated RLR styles	Power	60%
Resistor, fixed, precision wirewound RBR styles	Power	50%
Resistor, fixed, power wirewound (axial lead) RWR styles	Power	50%
Resistor, fixed, power wirewound (chassis mounted) RER styles	Power	60%
Resistor, Variable, wirewound, (trimming) RTR Styles	Power	50%
	Current	70%
Resistor, variable non-wirewound (trimming)	Power	40%
	Current	70%

TABLE 4-1: PARTS DERATING (cont'd)

PART TYPE	PARAMETER	DERATING (from Spec. Value)
Resistor, Thermally Sensitive (Thermistors)	Power	50%
Capacitors,		
Ceramic	Voltage	50%
Glass	Voltage	40%
Mica	Voltage	50%
Plastic	Voltage	50%
Solid Tantalum	Voltage	50%
Inductive devices (transformer, coil	Hot spot temperature	40°C below max
Filter, RFI	Current	75%
	Voltage	75%
	Temperature	20°c below max
Connector, electrical	Contact current	50%
	Working voltage	50%
Wire, electrical, insulated	Current	75%
	Voltage	75%

4.4.3.8 Transmitter Activation

An activation circuit should be incorporated into all ELT designs to filter G-switch closures. Most ELTs already include a latching circuit with some resistive-capacitive filtering along the lines of that shown in Figure 4.1. Component values should be selected to prevent ELT activation for G-switch closures of durations less than 11 ms. The design must also ensure that ELT activation is not inhibited for G-switch closures of between 11 and 16 ms duration which are representative a real crash conditions.

4.5 Antenna and Connector

In the antenna failure survey two thirds of the listed failures were concerned with a deployable secondary antenna that failed due to progressive corrosion.

This particular configuration could be improved (subject to successful testing) by changing the material of the antenna spring or its plating, improving the cover seal to exclude moisture, or by sealing the antenna access completely, subject to emergency opening only. On the other hand, this was the only design that offered the secondary antenna.

The antenna of course is an extremely important part of the transmitter and must be in a position to radiate after the emergency. Some ELT's are connected through coax cable to an aircraft antenna mounted externally. This connection and the external antenna can be damaged during the crash and thus negate the transmission from the ELT. On the other hand the largest number of emergency transmissions are from relatively undamaged aircraft.

Other ELT units are self contained, providing a 'whip' antenna as part of the unit. These units must be removed from the aircraft for optimum transmission, whether switched on manually or automatically by a 'G' switch. ELT's with attached whip antennas must be located close to a window, yet be more than a quarter wavelength from a vertical metallic member.

The ELT with both antenna options offers both capabilities and hence covers more emergency circumstances. It should not be discarded merely because of a poor material choice and enclosure design, or needing frequent inspection of the condition of the secondary antenna, and cleaning (if necessary) to ensure it remains fully effective.

4.6 Corrosion

In general corrosion is controlled by sealing out the corrosive elements, by using coating and finishes that are immune to corrosion in the given environment and by using metals which are similar on the galvanic scale.

Sealing considerations concern the integrity of the case of housing, the electrical connectors and any access covers. The number of mounting screws etc. which penetrate the cover should be kept to a minimum and any access holes must be sealed using rubber gasket washers under the screw head - the electrical connectors or antenna connector must be of a sealed type to eliminate water penetration. There are many types of military connectors to choose from which meet these requirements, depending on the style and number of pins required. Most of these use rubber sealing rings to prevent moisture entry.

Case materials of stainless steel or aluminum are the best choices for good corrosion resistance. Passivation process for the stainless steel and chemical conversion coatings for the aluminum further improve the corrosion resistance, as does an appropriate primer and external painting.

The choice of materials or plating inside the housing are important in order to prevent galvanic cell corrosion between dissimilar metals. Mounting screws, washers and mounting surfaces must be carefully chosen. Copper should be coated with solder or zinc plating.

Unsealed containers will normally breathe with changes in atmospheric pressure, altitude or temperature. This breathing can be controlled by suitable controlled 'leaks' and by placement of this 'leak' to ensure that condensation puddles are not drawn into the housing. The humidity inside the housing can be controlled further by the use of desiccant packs such as silica gel, montmorillonite, molecular sieve materials or vapor phase corrosion inhibitors. While these materials must be inspected and changed or recharged periodically they can be effective in small volumes such as an ELT.

As discussed above, the best protection for printed circuit cards and mounted components are conformal coatings of the polyurethane, acrylic or epoxy types. These are generally controlled by MIL-I-46058. The acrylics and some polyurethanes are single component fast drying coatings with good flexibility. The two component epoxies are generally harder and offer the best chemical resistance.
All conformal coatings require extreme cleanliness and surface preparation before coating, to eliminate dirt entrapment and other defects such as bubbles due to surface contamination and moisture.

The inclusion of batteries inside the ELT case is a major source of corrosion. Old batteries can leak electrolyte and give off corrosive gases. If these materials reach the electronics compartment significant damage to the electronics and its function can occur. Some types of cells ie. lithium have not been allowed since 1974. The gases which may vent from them are toxic, especially if vented into the cockpit. See comments re current technology in lithium cells in Appendix A. In the light of this care must be taken to separate the battery volume from the electronics, and to control any venting. This type of configuration would also allow inspection or change of batteries without breaking the 'seal' of the electronics compartment. Another approach to 'sealing' the electronics is to pot or encapsulate the electronics package into a solid unit. This can be repairable if an encapsulation material such as Dov Corning Sylgard elastomer 182 and 184 is used, or non-repairable if encapsulating epoxy is used. Silicone and other rubber encapsulants are also available offering more difficult repairability.

4.7 Power Output Spectrum

ELTs and EPIRBs (Emergency position indicating radio beacons) in current use were designed for reception by overflying aircraft using commercial VHF radio receivers. The majority of ELTs and EPIRBs were designed with no consideration of the possibilities of detection and location by a satellite-based system. Document RTCA/DO-183 (2) addresses this shortcoming by recommending a specification for the ELT output spectrum to aid satellite detection.

Each swept tone emission must have a clearly defined carrier frequency distinct from the modulation sideband components. The sidebands should be symmetrical about the carrier. Such an emission is referred to as coherent and will typically have 35% to 50% of total power in the carrier component. Many ELT's have their emission power distributed over a wide spectrum due to interaction between the oscillator and the modulator. These ELT's are considered non-coherent. Comparative spectra of coherent and non-coherent ELT and EPIRBs are shown in figure 4-2. Note the absence of a clearly defined carrier in the non-coherent spectrum.

The effect of non-coherent output on the success of location is illustrated in figure 4.3. In controlled field tests by NASA it was found that, at nominal output power, about 10% fewer non-coherent ELTs were located than coherent ELTs. When the output power was reduced the percentage difference in locatability increased dramatically. These NASA tests and figures are referenced in the Draft Nev Report No. 31-3/8 of CCIR XVII Plenary Assembly (10).

The quantitative requirement is that a least 30% of the power at 121.5 MHz be contained within ± 30 Hz of the carrier frequency, and 243 MHz within ± 60 Hz of the carrier frequency.

The upgrade of an ELT power spectrum would generally entail a circuit board re-design to incorporate load isolation between the crystal oscillator and the modulator stage. In some cases shielding between the antenna and the oscillator would need to be improved. The cost of additional parts would probably be less than $2, but the re-design costs could be as high as $15,000.

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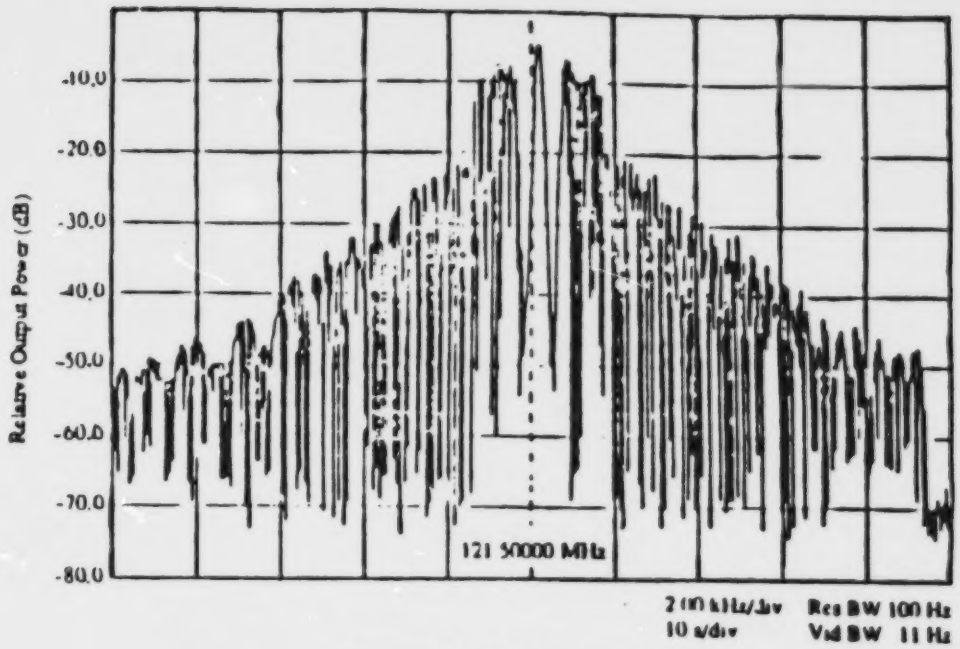

Figure 4-2A: Coherent ELT

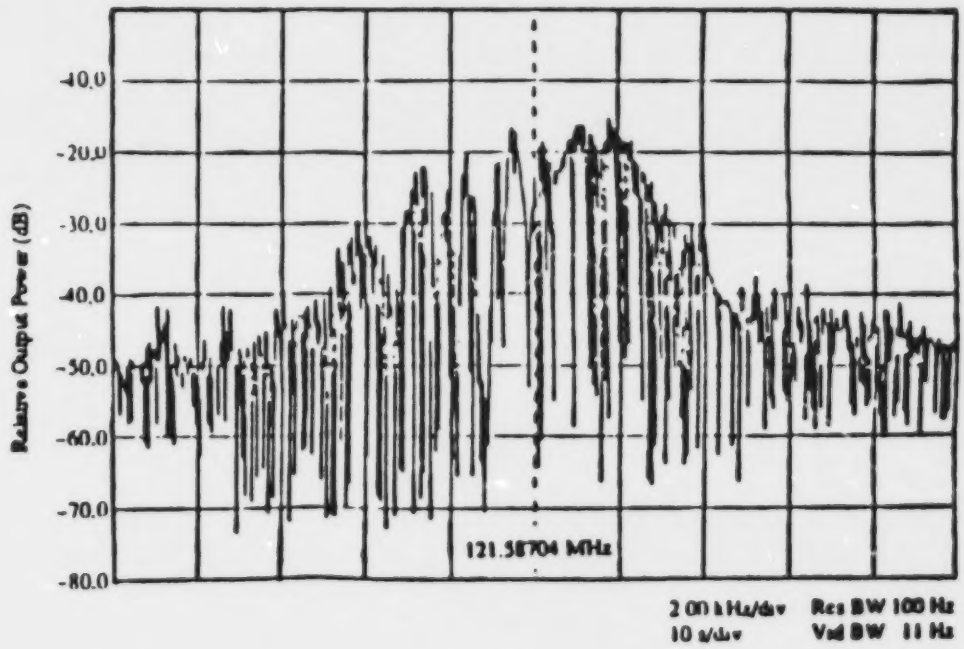

Figure 4-2B: Non-Coherent ELT

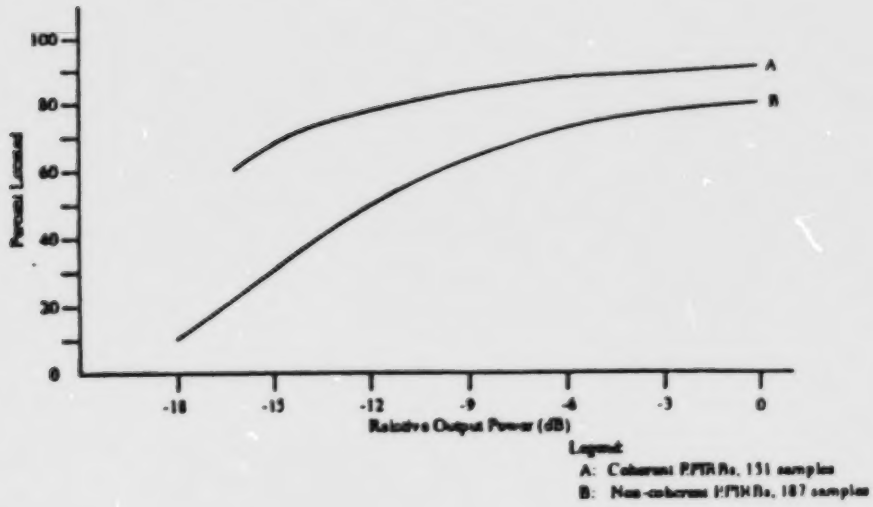

Figure 4-3: Percentage of ELTs Located

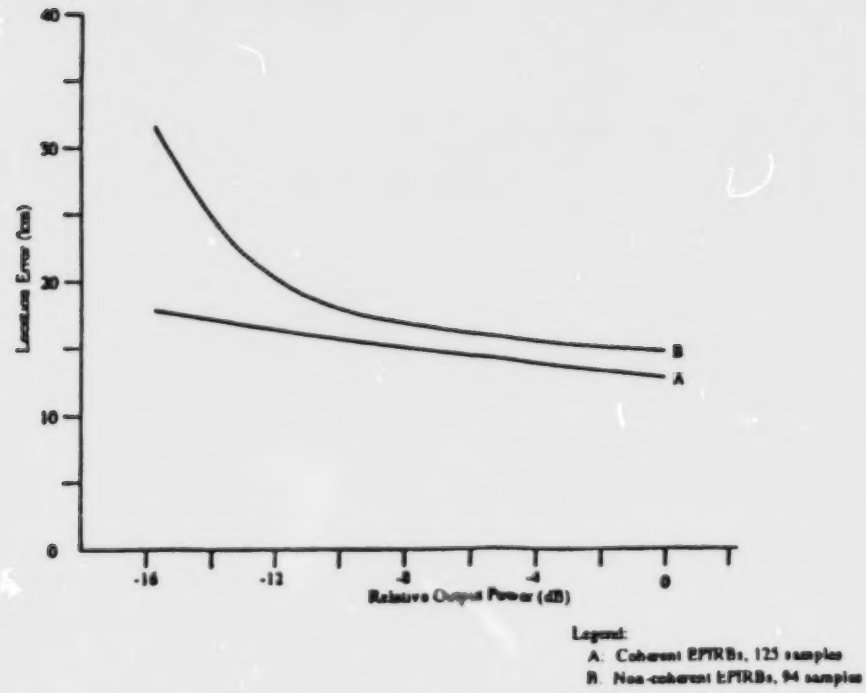

Figure 4-4: ELT Location Error

SECTION 5

COST BENEFIT ASSESSMENT

5.1 Rationale of Assessment

The basis for this cost benefit assessment of an ELT update program requires separate consideration of two problem areas; ELT generated false alarms, and ELT failures to operate in some crashes.

5.1.1. False Alarms

During the period of 1984 through most of 1987 the SAR group investigated over 500 ELT alarms annually that turned out to be false alarms. Most were traced quickly and some ceased without being traced. In the case of alarms that cease, if no reports of overdue or missing aircraft are received, the search is terminated. Although the ELTs which stay on the air can be found quickly, much valuable aircraft time and manhours are expended in tracing the false alarms. Most existing ELTs lack the precise frequency stability required to determine the location of the transmission from a single satellite pass. Therefore MCC procedure requires confirmation of the location by overflying aircraft, or overdue aircraft reports before SAR action can be taken. However, if a second satellite pass permits localization of the distress site, a SAR aircraft is launched even if the other confirmations are not received.

Total anuual cost for all false alarm investigations is estimated to be 1.5 million dollars: this is adopted as a working figure for the cost-benefit assessment on false alarm efforts.

5.1.2. ELT Failures in Crashes

Canadian Search and Rescue engages in approximately 30 searches per year when no ELT signal is detected. The cost of visual search can easily exceed one million dollars per mission. However, for this analysis an average of $100,000 per search is assumed.

5.1.3. Search and Rescue Cost Summary

False alarm investigation.	-- $1.5 million annually.
ELT aided rescue missions.	-- $0.8 million annually.
Visual search cost (non-functioning ELTs).	-- at least $3.0 million annually.

5.1.4 Estimated Savings

False alarm reductions resulting from implementation of the improvement program are estimated to be 40% annually. Annual saving would therefore be about $600,000.

Reduction of visual searches by 30% is probable. Savings in SAR costs would then be approximately $900,000 dollars annually.

Total estimated savings is = $1,500,000.

5.2 Upgrade Requirements

5.2.1. G-Switches

G-switches currently fitted to ELTs in general display undesirable sensitivity to non-crash disturbances. Poor ELT installation is partly responsible, but new switches meeting DO-183 requirements are required. A switch developed by Arnav for their new ELTs has been TSOd as part of the ELT assembly, and if proven satisfactory in the upcoming field trial, should be adopted if reasonably priced. This would avoid the development costs required in engineering an equivalent. Production switches, as a bought out item, would probably equal $50.00.

5.2.2 Installation Upgrade

Most of the existing ELTs are properly installed, others need re-evaluations as follows;

(1) The ELT shall be mounted on a stiff member of the aircraft structure not vulnerable to significant deflection under normal loads. G-switch orientation is critical.

(2) antenna installation requires a mounting that allovs the antenna to flex or bend rather than break under crash conditions. The connection between antenna and ELT must be survivable: the coaxial cable must be a foot or eighteen inches longer than needed to just connect the two units. The added length provides drip loops and permits strain relief to be arranged.

(3) A small remote control unit is required on or near the instrument panel. The unit would carry a mode switch (ON, ARM, TRANSMIT), a status lamp to shov when the ELT is armed, and on acoustic alarm or flashing light to indicate that the ELT is transmitting.

For installation, hourly rates by aviation electronic shops is assumed to be $50/hr. Reworking an installation to the upgrade standard will take from 2 to 6 hours depending on the aircraft configuration and the siting of ELT and g-switch. Installation costs ranging from 100 dollars to 300 dollars may be expected, with a probable average cost of 200 dollars. Assuming 50% of ELTs are already properly installed, the average installation upgrade is then 100 dollars.

The remote control panel costs as an independently manufactured part is estimated to be $150, installed. Therefore, the average total installation upgrade including a remote control panel is $250.00.

5.2.3. ELT Upgrade

Overhaul of ELTs in present use requires an assessment of the current condition of individual units. Where severe corrosion has damaged circuit boards or components the cost of repairs by local aviation radio repair shops would be prohibitive and quality control would be erratic. If large numbers of a given model are to be refurbished, the work should be done on a production line basis by the manufacturer or a large repair facility.

Recommended improvements of ELTs in good to excellent condition are as follows:

(1) replacement of g-switch with a new unit meeting DO-183 specifications,

(2) installation of a connector to connect the ELT to the remote control unit in the cockpit.

(3) circuit modifications to suit the remote control unit mode monitoring and mode switching functions.

5.2.4 Transmission Upgrade

The Federal Communications Commission (FCC) has decreed in PR Docket No. 87-133 (9) that all newly manufactured ELTs (also EPIRBs and CPLs), as of October 1, 1988, are required to be compatible with detection and position determination features of COSPAS-SARSAT.

Several manufacturers have indicated that the design changes to comply with the requirement are relatively minor. One time engineering costs would be about $15,000 and material cost would be typically less than $2 (U.S.)

However, to retrofit existing ELTs would not be feasible unless the change could be effected by parts substitution only. i.e. - without changing the printed wiring board.

5.2.5 Assumptions for Cost Estimate

Upgrading activities require two separate types of activity; factory activity in ELT modifications and manufacture of remote control units, and local area aviation electronics shops for installation modifications.

The initial phase of the factory work involves engineering design of specific model modifications, preparation of shop drawings and specifications and process instructions. The average design activity costs are estimated at $13,000 per model, averaged over 6 models. If we assume that 80% of the current population of ELTs require upgrading, then the amortized fixed costs are:

$$\frac{\$11000 \times 6}{20000 \times .8} = \$4.13 \text{ per unit}$$

Factory line activity involves ELT disassembly, stripping of coating, p.c.b. wiring and component changes, connector installation, re-assembly and functional test and then re-applying the conformal coating. After final reassembly there will be inspection and test. It would not be economic to do less than 200 units. On average, the factory assembly labour would be 9 hours. At 35 dollars per hour (including overhead) the unit labour cost would be:

$35 \times 9 = \$315.$

The general and administrative cost at 15% would be:

$(315 + 4) \times 0.15 = \$48.$

And gross profit at 10%:

$(315 + 4 + 48) \times 0.10 = \$37.$

Total cost of labour = $404.

5.2.6 Upgrade Program Costs Summary

Replacing the G-Switch	= $ 50.
Installation plus control panel	= $250.
ELT upgrade	= $400.
Total	= $700.

Assuming a population of 20,000 units, the total cost is

= $14 millions

5.3 Cost/Benefit Summary

From section 5.2.6, the total upgrade cost is

= $14,000,000.00

From section 5.1.4, the annual savings is

= $1,500,000.

Therefore, the break-even period is

= 10 years.

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SECTION 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 ELT Upgrade Feasibility

6.1.1 Conclusions

1. The data gleaned from the maintenance survey supports the operational evidence of low reliability of performance in actual crash situations.

2. Our estimate of the $700 average cost to upgrade existing ELTs is higher than the target cost of $500 (US).

3. The total cost of upgrading 20,000 ELTs is $14,000,000 against an estimated annual saving in Search and Rescue costs of $1,500,000. The resulting payback period of ten years is far too long.

6.1.2 Recommendations

We recommend that the Canadian general aviation community be urged to install ELTs conforming to TSO-C91a as soon as possible.

6.2 New ELT (TSO-C91 a) Field Test Plan

In order to test the new generation ELTs (TSO-C91a) in the Canadian environment, an economical field test plan is suggested as follows;

1) First: a survey is to be conducted among aircraft users in order to choose 100 aircraft with the worst combination of;

a) aircraft type; fixed wing, single reciprocating engine.

b) usage; highest number of landings and take-offs.

c) runway; gravel, grass or winter runways.

d) pilots; the least experienced.

e) Because of the extremes of Canadian climate, aircraft regularly operating over wide temperature and pressure variations, and in adverse flying conditions should also be included in the field test plan.

2) Leigh originally recommended that the new ELT be installed without removing the old ELT. However, the ELT Working Group met on May 13, 1988 to discuss the advantages and disadvantages of having either two ELTs or one ELT on board the test aircraft. The group decision was to install one new ELT instead of one new and one old ELT. At this writing Transport Canada is in the process of certifying the ARNAV ELT-100 and ELS-10 for use in Canada.

3) The new ELTs are then to be monitored for a period of two years.

4) Considering the above, the number of incidents, including false alarms, are expected to be 11 to 26 for the 100 aircraft during the two year test period.

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(10) Shane, J., REPORT ON THE TESTS PERFORMED ON SAFT LITHIUM/SULPHUR DIOXIDE CELLS TYPE LX26/49, Leigh Instruments Limited, Carleton Place, Ontario K7C 4J5, May 1986, TS801632 Issue 1.

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APPENDICES

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APPENDIX A

ELT SUPPLIERS QUESTIONNAIRE

1. What models of ELT do you sell?

2. What is your estimate of the quantity of each ELT model, that you supply, currently in service in Canada.

3. Do you also retail through distributors ?

4. If yes, plese list distributor name(s), location(s), and telephone number(s).

5. What models do you service, besides those that you sell?

6. Hov many units of each model do you recertify annually?

7. Hov many battery replacements do you do each year?

8. Hov many of each model do you repair or return to the factory each year?

9. Do you perform a burn-in test on each repaired unit?

10. Would you be willing to provide Leigh Instruments with copies of your service schematics and procedures? They would be held in strict confidentiality and return to you or destroyed upon completion of the study contract.

ELIGIBLE SUPPLIERS OF ELTs IN CANADA

CANADIAN AIRMOTIVE LTD. MR. ERIC MAULE	RR No. 4, Hwy 44 ALMONTE, ON K0A 1A0	613 256 1411
DORNE & MARGOLIN, INC	BOHEMIA, NY 11716 2950 VETERANS MEMORIAL HWY	516 585 4000
MARTECH, INC.	FT LAUDERDALE, PO BOX 1539 FL 33302	305 463 3451
NARCO AVIONICS	FT WASHINGTON PA 19034	215 643 2900
POINTER AVIONICS LTD	1235 SHAWSON DR MISSISSAUGA, ON L4W 1C4	416 678 1600
TECHNISONIC INDUSTRIES LTD	MISSISSAUGA, ON L4Z 1N8 450 MATHESON BLVD. UNIT 55	416 276 8313

APPENDIX B

RELIABILITY PREDICTION

B.1 Introduction

The following reliabiity prediction has been done using the part stress analysis method of MIL-HDBK-217D (1).

This method of prediction involves establishing valid operational reliablity factors such as device quality, operating temperature, circuit complexity, device learning factor, voltage stress derating factor and application environment factor.

Most of the above factors are either circuit dependent or environment independent except for the application environment factor, which is chosen on a best fit basis from a set of possible environmental scenarios. (See attachment) In this case, Manpack was chosen over airborne as the most applicable environmental factor since an ELT generally does not operate when the aircraft is airborne.

Other non-environmental factors were chosen based on available data.

Where data was not available, assumptions based on field experience where made.

Data is ranked by order of contribution to the total failure rate.

1) DEPARTMENT OF DEFENCE, WASHINGTON DC 20301, MIL-HDBK-217E; MILITARY HANDBOOK RELIABILITY PREDICTION OF ELECTRONIC EQUIPMENT

Table B-1

Prediction 1
Basic Reliability - Pointer ELT

COMPONENT	DESCRIPTION	30°C STRESS	FAILURE RATE	QTY	TOTAL FAILURE RATE
Switch		-	5.46	1	5.46
Cap. Elect.	6.8 uF 10WV	1	4.37	1	4.37
2N4853	Q1, UJT	<0.1	3.6	1	3.6
Resistors	Various Carbon	<0.5	0.132	25	3.3
Capacitors	Various	0.5	0.143	16	2.29
Crystal	Y1, 121.5 MHz	-	0.906	1	0.906
2N2222A	Q3, 4 Multivibrator	0.9	0.143	2	0.287
2N5179	Q7, Buffer Amp	0.7	0.18	1	0.18
Inductor	L1, Variable	-	0.176	1	0.176
Inductor	L2, Fixed	-	0.088	1	0.088
Inductor	L3, Fixed	-	0.088	1	0.088
Transformer	T1, Fixed	-	0.088	1	0.088
Diode	CR1,2 1N4148	0.4	0.0315	2	0.063
2N918	Q6, Oscillator	0.35	0.038	1	0.038
PT8922	Q8, RF Power	<0.1	0.0125	1	0.0125
2N2222A	Q2, 5 Amp & Gate	<0.1	0.0027	2	0.0054
	Total			58	
	Total Failure Rate (Failures per million hours)				20.95
	MTBF (Hours)				47,732

Table B-2

Prediction 2
Basic Reliability - Deft 1 ELT

COMPONENT	DESCRIPTION	30°C STRESS	FAILURE RATE	QTY	TOTAL FAILURE RATE
Cap, Variable	RF Tuning	-	17.68	4	70.72
Cap, Elec	Timing, PWR	-	4.03	3	12.1
Capcitors	Various	-	0.286	14	4.004
Inductors	RF Chokes	-	0.968	4	3.872
2N3563	Q2, RF Buffer	0.5	3.33	1	3.33
PCB Inductor	Spiral	-	0.968	3	2.904
SCR, 1038	Latch	-	2.64	1	2.64
Resistors, Carbon	Various	-	0.145	16	2.32
Switch, Function	Standard, 3 PST	-	2	1	2
2N3563	Q1, RF OSC	0.1	1.69	1	1.69
Crystal	Y 1, Standard Quartz	-	0.906	1	0.906
IC, 081	A1, Follower	-	0.476	1	0.476
2N3866	Q3, RF Power	0.1	0.35	1	0.35
4013	IC2, Divide by 2	-	0.217	1	0.217
7556	IC1, Sweep Gen.	-	0.217	1	0.217
Fuse	F1, 2A Fuse	-	0.08	1	0.08
2N3906	Q4, Gate	0.1	0.01	1	0.01

Total	55
Total Failure Rate (Failures per million hours)	107.8
MTBF (Hours)	9,276

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APPENDIX C

DEFECTS ANALYSIS TABLES

List of Tables

C-1 Maintenance Defects by Model.
C-2 Component Defect; G-Switch.
C-3 Component Defect; Corrosion.
C-4 Component Defect; Circuit Board.
C-5 Component Defect; Antenna & Connector.
C-6 Component Defect; Battery.
C-7 Component Defect; Miscellaneous.

TABLE C1: MAINTENANCE DEFECTS BY MODEL

ELT MODEL	REASON FOR SERVICE		CORROSION	BATTERY	ANTENNA	G-SWITCH	CCA	OTHER	REMARKS
	INSP	OTHR							
ALL MODELS	1077	15	40	25	31	45	40	16	TOTAL SURVEYED = 1092 TOTAL DEFECTS = 197 % DEFECTS = 18.0%
DEFECT %			20.3	12.7	15.7	22.9	20.3	8.1	
TOTAL FORWARD									

TABLE C1: MAINTENANCE DEFECTS BY MODEL

ELT MODEL	REASON FOR SERVICE		CORROSION	BATTERY	ANTENNA	G-SWITCH	CCA	OTHER	REMARKS
	INSP	OTHR							
NARCO ELT-10/10C	257	4	20	4	26	6	7	3	1. MOST CCA FAILURES DUE TO CORROSION 2. MOST ANTENNA DAMAGE DUE TO CORROSION 3. FOUR CASES OF UNAPPROVED BATTERY (MFR. SPEC.) 4. ONE ON/OFF SWITCH 5. ONE BOOT TORN 6. ONE CASE DAMAGED
EMERGENCY BEACON CORP. EBC-102/102A	255			1	1	3	5	1	1. ONE BATTERY NOT TO MFR. SPEC 2. ONE DEFECTIVE TEST SWITCH 3. BROKEN G-SWITCH SPRING 4. FOR CCA DEFECT IS REPLACED IN WARRANTY 5. GENERAL OVERHAUL
EBC-302	12					1			
TOTAL FORWARD	524	4	20	5	27	10	12	4	

TABLE C1: MAINTENANCE DEFECTS BY MODEL

ELT MODEL	REASON FOR SERVICE		CORROSION	BATTERY	ANTENNA	G-SWITCH	CCA	OTHER	REMARKS
	INSP	OTHR							
POINTER C-4000	97	6	4	5	2	4	14	3	1. TWO BATTERIES NOT TO MFR. SPEC 2. ONE BATTERY CONN DAMAGE OF REMOTE CTRL CORROSION DAMAGE 5. ONE CRYSTAL FAILURE 6. ONE BROKEN WIRE
TOTAL FORWARD	621	10	24	10	29	14	26	7	

TABLE C1: MAINTENANCE DEFECTS BY MODEL

ELT MODEL	REASON FOR SERVICE		CORROSION	BATTERY	ANTENNA	G-SWITCH	CCA	OTHER	REMARKS
	INSP	OTHR							
DEFT-1/1A	182	1	3	10	1	3	5	2	1. EIGHT CASES OF BATTERY NOT TO MFR. SPEC. 2. TWO LEAKING BATTERIES 3. TWO CRYSTALS FAILED 4. TWO MODULATORS FAILED 5. ONE CASE OF LEAD CLIPPING LEFT
DORNE & MARGOLIN									
ELT-6/6.1	115	3	3	2		14	3	1	1. ONE LEAKING BATTERY 2. ONE CASE OF LOOSE PARTS
ELT-8/8.1	25		1	1			1		
TOTAL FORWARD	943	14	31	23	30	31	35	10	

TABLE C1: MAINTENANCE DEFECTS BY MODEL

ELT MODEL	REASON FOR SERVICE		CORROSION	BATTERY	ANTENNA	G-SWITCH	CCA	OTHER	REMARKS
	INSP	OTHR							
LEIGH SYSTEMS SHARC-7/7K	76		5	1		9	3	2	1. TWO CRYSTAL FAILURES 2. ONE BATTERY WARRANTY REPLACE-MENT 3. ONE DAMAGED CASE
TECHNISONIC TEL 82	32		1		1	2	1	2	1. LEAKING BATTERY 2. TWO DAMAGED WIRES
CCC/COLLINS CIR-II	8	1		1		1	1	2	1. ONE BATTERY NOT TO MFR. SPEC 2. ONE MECHANICAL INTERFERENCE
MARTECH EB-2 BCD/BW	12		1						
GARRET MFG RESCU 88	6		2			2			
TOTAL FORWARD	1077	15	40	25	31	45	40	16	TOTAL DEFECTS = 197

TABLE C2: COMPONENT DEFECT: G-SWITCH

ELT MFR/MODEL	WEAK	STIFF	INTERMITTENT			OTHER	REMARKS
NARCO ELT-10/10C	3		1			2	1. MOST OTHERS ARE OVERSENSITIVE OR INTERMITTENT
EBC-102/302-G7	1	1				2	
POINTER C-4000	1		1			2	2. SOME ARE U/S DUE TO CORROSION
DEFT-1/1A						3	
D&M ELT-6/8	3	1	1			9	
LEIGH SYS. SHARC-7						9	
TECHNISONIC TEL-82						2	
COLLINS CIR-11						1	
MARTECH EB-2 BCD						--	
GARRETT RESCU 88						2	
TOTALS	8	2	3			32	45

TABLE C3: COMPONENT DEFECT: CORROSION

ELT MFR/MODEL	BATTERY LEAK	WATER				OTHER	REMARKS
NARCO ELT-10/10C	7	2				11	1. MOST OTHER SOURCES ARE PROBABLY BATTERY LEAKAGE.
EBC-102/302/G7							
POINTER C-4000	1	3					
DEFT - 1/1A	1	2					
D&M ELT-6/8	3					1	
LEIGH SYS. SHARC-7	5						
TECHNISONIC TEL-82						1	
COLLINS CIR-11						1	
MARTECH EB-2 BCD						--	
GARRETT RESCU 88						2	
TOTALS:	17	7				16	40

TABLE C4: COMPONENT DEFECT: CIRCUIT BOARD

ELT MFR/MODEL	MODULATION	RF AMPL.	RF OSC.	TRANSISTORS	CRYSTAL	CORROSION	OTHER	REMARKS
NARCO ELT-10/10C		4	1			1	1	1. "OTHERS" PROBABLY SEMICONDUCTOR OR ELECTROLYTIC CAPACITOR FAILURES.
EBC-102/302-G7	4	1						
POINTER C-4000	6	5	1			1	1	
DEFT - 1/1A	2	1			2			2. CORROSION MOSTLY DUE TO BATTERY LEAKS.
D&M ELT - 6/8	2	1					1	
LEIGH SYS. SHARC-7	1				2			
TECHNISONIC TEL-82	1							
COLLINS CIR-11							1	
MARTECH EB-2 BCD								
GARRETT RESCU 88								
TOTALS:	16	12	2	0	4	2	4	40

TABLE C5: COMPONENT DEFECT: ANTENNA & CONNECTOR

ELT MFR/MODEL	CORROSION	CONNECTOR DAMAGE	LOST	BROKEN	OTHER	REMARKS
NARCO ELT-10/10C	16	2	1	1	6	
EBC-102/302-G7		1				
POINTER C-4000			1		1	
DEFT - 1/1A		1				
D&M ELT - 6/8						
LEIGH SYS. SHARC-7						
TECHNISONIC TEL-82					1	
COLLINS CIR-11						
MARTECH EB-2 BCD						
GARRETT RESCU-88						
TOTALS	16	4	2	1	8	31

TABLE C6: COMPONENT DEFECT: BATTERY

ELT MFR/MODEL	LIFE <2 YR	LEAKAGE	UNAPPROVED	OVERDUE	REMARKS
NARCO ELT-10/10C			4	–	1. SOME ELT MFRS REQUIRE USE OF A SPECIFIED BATTERY, AS ITS STRUCTURE IS PART OF THE TUNING OR LOADING OF THE RF AMPLIFIER.
EBC - 102/302/G7			1	–	
POINTER C-4000	4		1	–	
DEFT - 1/1A	9	1		–	
D&M ELT - 6/8	1	2		–	
LEIGH SYS. SHARC-7	1			–	
TECHNISCONIC TEL-82				–	
COLLINS CIR-11		1		–	
MARTECH EB-2 BCD				–	
GARRETT RESCU-88				–	
TOTALS	15	4	6	53	78

TABLE C7: COMPONENT DEFECT: MISCELLANEOUS

ELT MFR/MODEL	CONNECTOR	ACCESSORY	SWITCH	LEADS	OTHER	REMARKS
NARCO ELT-10/10C	1		1		1	
EBC - 102/302/G7					1	
POINTER C-4000	3					REMOTE CTRL & CONNECTOR
DEFT - 1/1A			1		1	
D&M ELT -6/8					1	
LEIGH SYS. SHARC-7					2	
TECHNISONIC TEL-82				2		
COLLINS CIR-11	1				1	
MARTECH EB-2 BCD						
GARRETT RESCU-88						
TOTALS	5	1	2	2	7	17

APPENDIX D

AIR INCIDENTS AND ELT ALERTS

1986 - 1987

BY

NATIONAL SEARCH AND RESCUE

SECRETARIAT

National Search and Rescue Secretariat
Secretariat national Recherche et sauvetage

365 Laurier Avenue West
17th Floor, Journal Tower South
Ottawa, Ontario
K1A 0K2

January 19, 1989

Mr. Alan J. Armstrong
Project Manager, ELT Study
Leigh Instruments Limited
115 Emily Street, P.O. Box 82
Carleton Place, Ontario
K7C 3P3

Re: SAR Statistics for Canada

Dear Mr. Armstrong:

The attached table contains statistics on air incidents and ELT activations which I hope will be useful for your study. The information is not exactly what you requested but it is the closest that we can provide.

I suggest that you contact Major Brad Gibbons, Directorate of Air Operations and Training (DAOT-5), at 992-4131 for the cost information that you require.

Sincerely,

Amanda McDonald
Senior Advisor
Information and Analysis

AM/lc

c.c. Maj. B. Gibbons

APPENDIX D

AIR INCIDENTS AND ELT ALERTS

	1986	1987
TOTAL NUMBER OF AIR INCIDENTS	1,097	1,106
NO. OF AIR INCIDENTS WHERE INITIAL ALERT METHOD IS ELT	609	570
No. of these where incident is a distress incident and primary SAR resources tasked	29	14
No. of these where incident is a distress incident but no primary SAR resources were tasked	15	7
No. of these where incident is temporary distress or a reactivated case	7	8
No. of these where incident is either a non-distress or a false alarm	558	541
No. of non-distress or false alarms for which ELT reason for activation was accidental	147	195
No. of non-distress or false alarms for which ELT reason for activation is not known	360	314
No. of non-distress or false alarms for which ELT reason for activation is for other reason, including test	51	32

SOURCE: National Search and Rescue Secretariat
Information and Analysis
365 Laurier Ave, West
17th Floor, Journal Tower South
Ottava, Ont.
K1A OK2

APPENDIX E

CANADIAN ACCIDENT DATA

1980 - 1988

BY

CANADIAN AVIATION SAFETY BOARD

Canadian Aviation Safety Board
Bureau canadien de la sécurité aérienne

P.O. Box 9120
Alta Vista Terminal
Ottawa, Ontario
K1G 3T8

Your file Votre référence

Our file Notre référence

March 15, 1989

680-4

Mr. A. Armstrong
Leigh Instruments
115 Emily Street
Carleton Place, Ontario
K7C 4J5

Dear Mr. Armstrong:

Further to our recent conversation, enclosed are tables of aircraft accidents in Canada for which emergency locator transmitter and airport proximity data are available.

I would caution you that the assignment of factors contributing to causing an accident are assigned late in the investigation process. Thus, it is quite possible that if the tables of ICAO factor group by airport proximity were prepared in the future, a different result would be obtained.

Should you have any further requirement for data of this nature, please do not hesitate to contact us.

Yours truly,

John R. Chadwick

J. Chadwick
Superintendent, Statistical Analysis

Attachment

ACCIDENTS IN CANADA 1980 - 1988
AIRPORT PROXIMITY BY ELT USAGE

	ELT USAGE					
	INSTALLED EFFECTIVE	INSTALLED NOT EFFECTIVE	NOT AVAILABLE	PORTABLE EFFECTIVE	PORTABLE NOT EFFECTIVE	TOTAL
	ACCIDENTS	ACCIDENTS	ACCIDENTS	ACCIDENTS	ACCIDENTS	ACCIDENTS
AIRPORT PROXIMITY						
AERODROME	89	270	75	0	13	447
SEA BASE	10	19	1	0	0	30
HELIPORT	4	4	0	0	0	8
CIRCUIT	10	16	6	1	0	33
0-.4KM	25	25	16	0	0	66
.4-.8KM	6	9	8	0	1	24
.8-1.2KM	6	4	5	1	0	16
1.2-1.6K	7	14	4	1	0	26
1.6-3.2K	13	14	9	1	0	37
3.2-4.8K	4	3	3	0	0	10
4.8-6.4K	5	6	3	0	0	14
6.4-8 KM	9	9	3	1	1	23
> 8 KM	203	265	77	16	18	579
TOTAL	391	658	210	21	33	1313

ACCIDENTS IN CANADA 1980 - 1988
AIRPORT PROXIMITY BY ICAO FACTOR GROUPS

AIRPORT PROXIMITY	PILOT PERCEPTION	OPERATION OF EQUIPMENT	PILOT DECISION	PROCEDURES	AIRCRAFT HANDLING	PILOT - MEDICAL	PILOT - MISCELLANEOUS	PERSONNEL - MISCELLANEOUS	AIRFRAME FACTORS	POWER PLANTS	AIRCRAFT SYSTEMS
AERODROME	184	305	381	429	651	14	193	258	320	98	42
SEA BASE	12	15	32	29	43	3	10	15	10	4	0
HELIPORT	4	2	3	4	1	0	5	2	0	2	0
PLATFORM	0	0	1	1	0	0	2	1	0	0	0
CIRCUIT	12	16	16	21	18	4	12	15	4	17	1
0-.4KM	28	41	65	68	59	4	23	17	4	31	1
.4-.8KM	6	13	15	25	16	2	13	7	0	14	0
.8-1.2KM	5	6	11	13	7	0	3	8	1	9	1
1.2-1.6K	4	13	13	27	9	8	6	8	3	9	1
1.6-3.2K	6	16	12	37	11	5	18	15	5	20	1
3.2-4.8K	5	5	6	16	5	1	2	4	1	9	0
4.8-6.4K	3	4	9	13	5	1	5	6	2	10	1
6.4-8 KM	4	10	13	20	6	4	10	8	4	11	0
> 8 KM	140	151	374	486	256	78	236	145	72	212	13
TOTAL	413	597	951	1189	1087	124	538	509	426	446	61

(CONTINUED)

ACCIDENTS IN CANADA 1980 - 1988
AIRPORT PROXIMITY BY ICAO FACTOR GROUPS

	INSTRUMENTS AND EQUIPMENT	ROTORCRAFT FAILURE	AERODROME FACTORS	WEATHER FACTORS	TERRAIN	MISCELLANEOUS FACTORS
AIRPORT PROXIMITY						
AERODROME	13	10	292	254	93	85
SEA BASE	0	0	13	24	11	6
HELIPORT	0	2	1	5	2	0
PLATFORM	0	0	0	0	0	0
CIRCUIT	1	1	7	9	11	6
0-.4KM	4	0	21	31	23	12
.4-.8KM	0	0	0	9	4	3
.8-1.2KM	0	1	0	5	6	3
1.2-1.6K	1	2	1	10	13	3
1.6-3.2K	2	0	0	11	12	8
3.2-4.8K	2	2	0	9	12	1
4.8-6.4K	0	0	1	5	7	2
6.4-8 KM	0	1	1	8	16	6
> 8 KM	13	36	29	293	279	122
TOTAL	36	55	366	673	489	257